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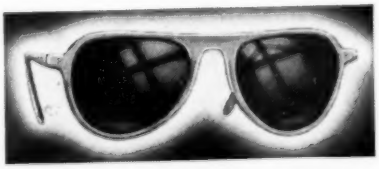

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Vol. 16 MARCH, 1939 No. 3

CONTENTS

ORIGINAL PAPERS

The Effect of Loss of Sleep on Visual Tests. Brant Clark and Neil Warren 80

Heterophoria and Aniseikonia. Robert E. Bannon 96

A Comparison of the Betts Tests of Visual Sensation and Perception with a Standard Clinical Examination. Herman Molish and Ellsworth Reese 110

EDITORIALS

Health Insurance. Carel C. Koch 118

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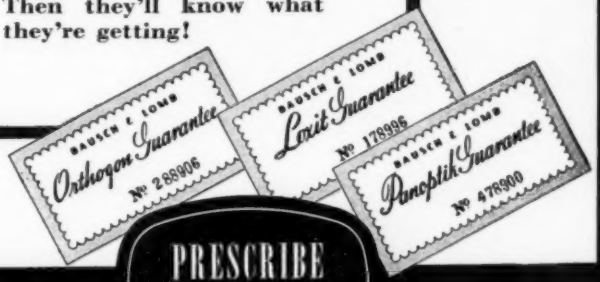

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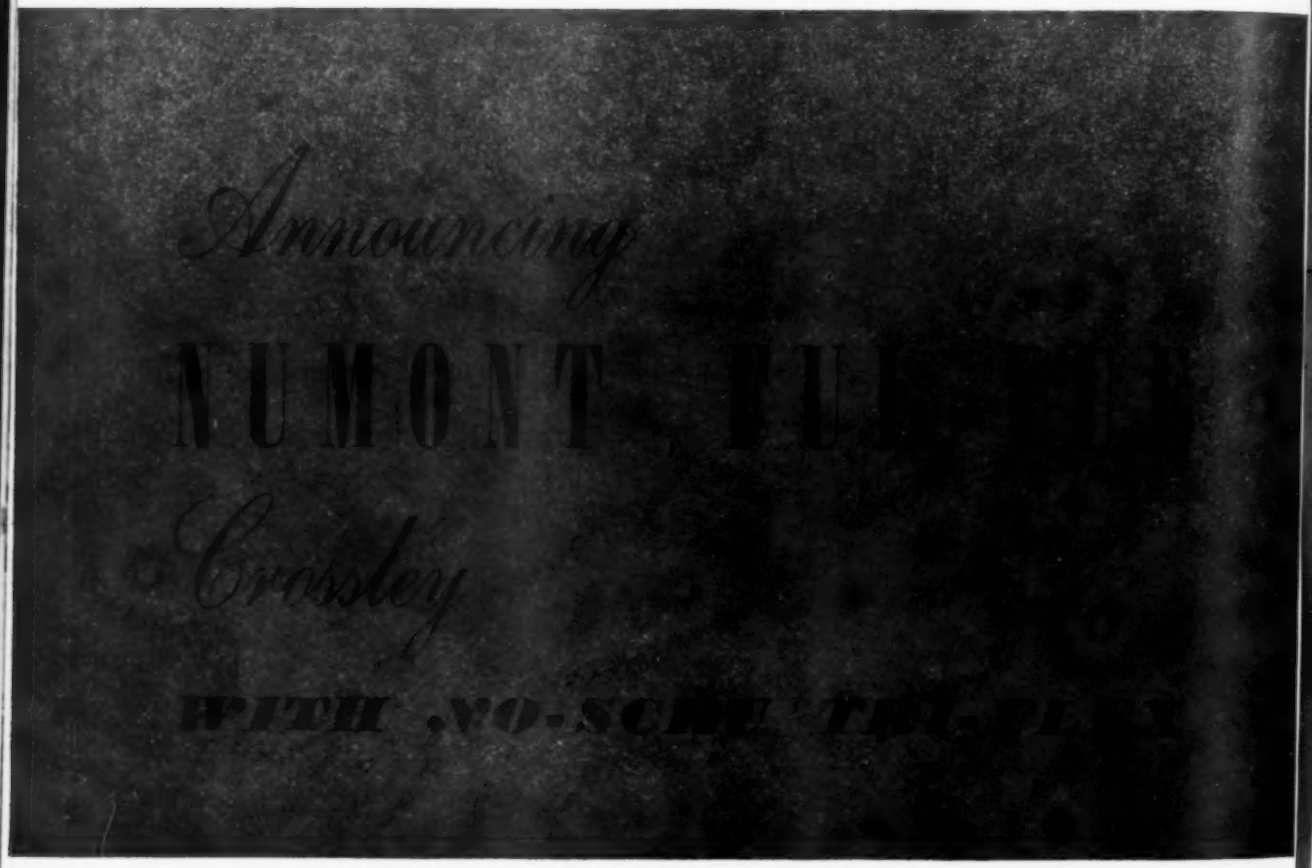

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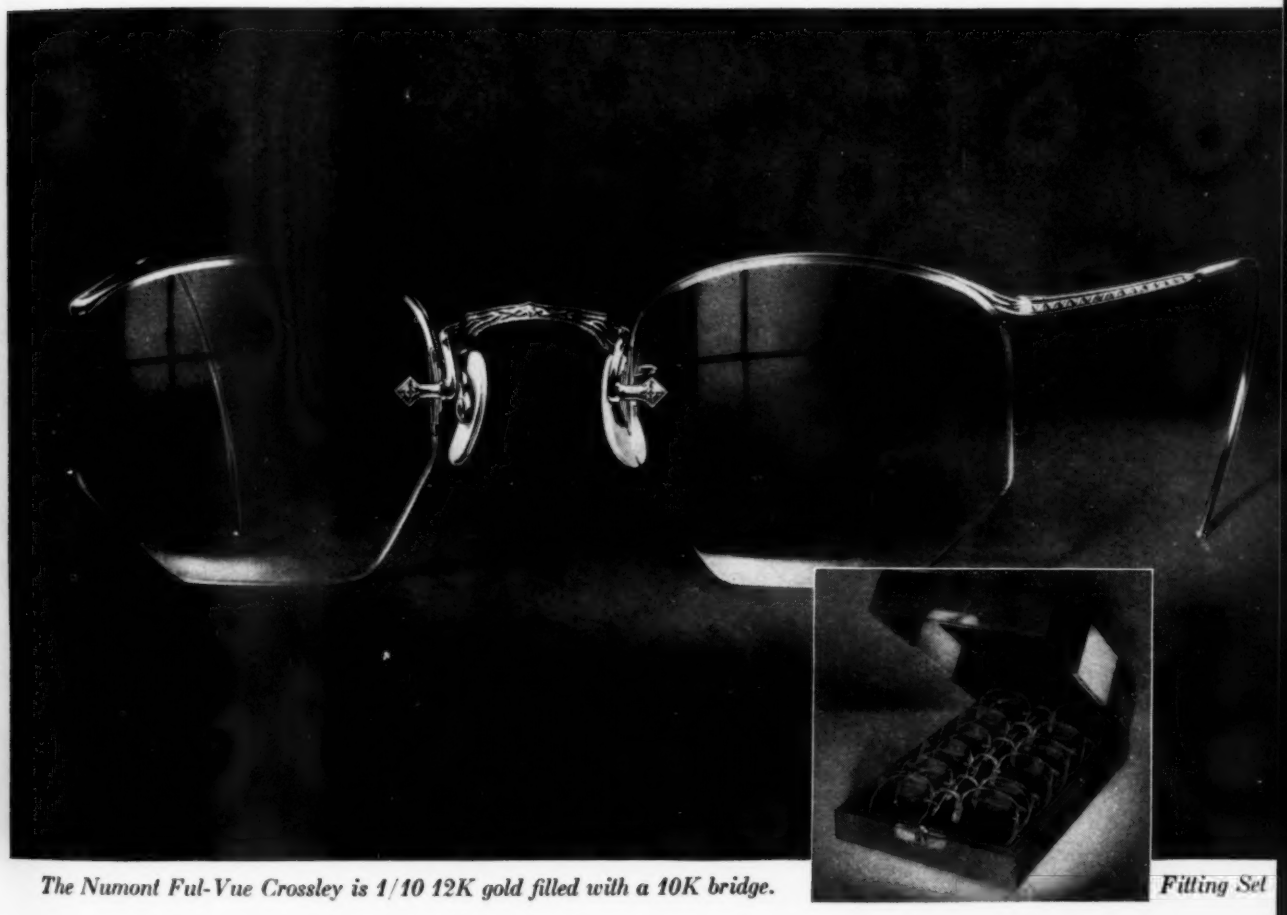

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THE EFFECT OF LOSS OF SLEEP ON VISUAL TESTS*

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Neil Warren, Ph.D.
University of Southern California

INTRODUCTION

Numerous investigators have conducted studies to determine both the psychological and physiological reactions during prolonged vigils and periods of reduction in sleep. For the most part, the results of these studies have been negative as far as the test results are concerned, and in those cases where the results have been positive, they were not in proportion to the loss of sleep. This has been true because the normal sleep ration undoubtedly leaves a very large safety factor over and above the actual needs of the individual. Moreover, the test methods are inadequate to show reduction in efficiency for the reason that the subjects are able to compensate during the relatively short periods of the tests. However, anyone who has gone without sleep for 48 hours or more can testify that his subjective reactions do not correspond to the test results, and the introspections of experimental subjects show very marked subjective changes. Without exception, the subjects reported that they felt tired, desired sleep, had to put forth additional effort, and so forth. Moss (12), Weiskotton (14), and Cooperman (6) give extended discussions of earlier experiments, so only studies that bear directly on the results of this investigation will be reviewed. It is worth noting, however, that most of the studies, with the exception of Weiskotten's have been concerned with tests before and after a prolonged vigil and have been less concerned with changes during the vigil.

As far as the authors are aware, no extended series of optometric tests have been made during prolonged vigils or during experimental fatigue, although a number of investigators have studied the problem.

*Submitted for publication Jan. 5, 1939.

Cooperman, et al (6) conclude as a result of accurate studies of visual acuity during prolonged vigils, " . . . visual acuity did not show any consistent deviation from normal, . . ." although they did find the threshold for pain lowered for their 6 subjects. Lee and Kleitman (11) found no consistent variations in the pupillary reflex under similar conditions.

As early as 1912 Howe (9) studied the experimental fatigue of accommodation and found fatigue curves comparable to those found by Mosso's early investigation with the ergograph. In a series of more recent experiments, Berens and Stark (2) and Berens (1) were unable to find such a clear cut fatigue phenomenon. In their experiments only about 30% of the cases exhibited the fatigue curves. Kurtz (10) has studied changes in dynamic skiametry, accommodation, and reading during a 30 minute period of intense visual effort. Although there was a small reduction in reading efficiency, only one subject showed a reduction in accommodation.

Bills (3, 4, 5) has made several studies of blocking during fatigue which do not involve visual factors predominantly, but which are significant to the problem. He uses fatigue to mean a measurable decrement in either output, organic state, or subjective feeling tone resulting from continuous performance. He has found that homogeneity is the important factor in causing fatigue, i.e. if the task involves relatively identical elements, there will be greater fatigue, and he has shown that mental performance is actually not continuous but interspersed with "blocks." The term "block" is used to refer to those periods occurring during mental work when subjects seem unable to make a response, and cannot continue even by means of additional effort, until a short period of time has elapsed. Bills believes that these blocks tend to eliminate the decrement in fatigue, correspond to the rhythm of attention, and are associated with the refractory phase. Bills has found that the number and size of these blocks increase during fatigue and in general he believes that blocks increase the amount of rest gained and hence enable the subject to maintain his speed and compensate for fatigue. Warren and Clark (13) found that these blocks increased during the prolonged vigil in spite of the fact that the average response remained the same.

EXPERIMENTAL PROCEDURE

The experimental vigil lasted approximately 65 hours, from 5:30 AM Friday morning until 10:30 PM Sunday night. Four students in

psychology acted as subjects, and all were paid for their time as an added motivation. A complete physical examination was given each subject before the test and on the morning of the last day. Three of the subjects completed the experiment, and the fourth completed approximately 48 hours. Preliminary tests were made on three of the S's before the vigil began and post-tests were given after the experiment was completed, i.e. after the subjects had normal sleep. The preliminary test was not given the fourth subject because he volunteered to act as a subject the day that the test began. The tests were begun at 6:30 AM, and the complete battery was given in the morning. On Friday, (the first day), the subjects were permitted to attend classes as usual, but from midnight until the completion of the experiment, they were not permitted to be alone at any time.

Various methods were used to keep them awake, e.g. games of various sorts and walks were particularly effective. The tests were made frequently enough to keep them occupied a large part of the time. Experimenters and assistants worked in shifts. A majority of the tests were made by the authors, but three graduate students made some of them. All of the optometric tests were made by the first author except peripheral vision, visual acuity and depth perception. About 12 assistants worked in shifts keeping the subjects awake; however, near the end of the testing period, it was impossible to eliminate naps entirely. One subject had a fifteen-minute nap Sunday morning, but with this exception, the naps were limited to a few seconds. Another subject declared himself unable to continue after being awake for 48 hours. He was given a final series of tests and permitted to leave. All of the subjects co-operated well throughout the testing period. The tests were given at ten-hour intervals on a regular pre-arranged schedule.

The results to be reported in this paper include the data from the following tests: static retinoscopy, dynamic retinoscopy, near and far point ductions and phorias, amplitude of accommodation, visual acuity, peripheral vision, and depth perception. These optometric tests were made using common clinical procedures and standard refracting equipment.[1]

The series of tests reported in this paper cover only a part of the tests given during this vigil. Measurements of blocking have already been reported (13). In addition to these tests, the following were given:

[1] The authors are indebted to Dr. E. A. Hutchinson, whose thorough cooperation in permitting the use of the complete clinical facilities of the Los Angeles School of Optometry, made this series of tests possible.

phonographic records of speech, binocular eye movement photography of reading, convergence, and simple inter-fixation movements, steadiness, writing, and free-association. The results of these tests will be reported elsewhere.

The static retinoscopic tests were made with fixation on a 20/200 E, placed at 20 feet using a mirror. The retinoscope was a standard electric type, and the working distance was 66 cm. The working lenses were placed before both eyes before the measurements were begun. The tests of dynamic retinoscopy were made using the same retinoscope with working distance and fixation at 40 cm. The fixation objects were small inverted letters which the subject named during the test, and the measurement was made by finding the lowest positive lens to neutralize the shadow movement.

Ductions were taken at 20 feet using a small Snellen chart with letters of varying acuity values, while the near point ductions were taken on a reduced Snellen chart placed at 13 inches. In both the distant and near tests the prisms were slowly increased in power, first over one eye and then the other, until diplopia was reported and then reduced until single vision occurred. The phorias were taken at the same distances using the same fixation objects. A 6△ prism base-up was placed in front of the left eye, and the deviation was measured with a rotary prism placed before the right eye. In both the duction and phoria measurements the examiner did not attempt to observe the amount of prism being used until after the subject reported alinement or diplopia.

Visual acuity was measured using the black Landoldt split ring on a white ground as a test object. This was used because it gave a convenient method which practically eliminated memorizing the test. The chart was illuminated with approximately 25-foot candles in a room having good general illumination. The chart was rotated on successive tests.

Peripheral vision was measured for white, blue, red, and green using the Ferree-Rand perimeter (7). Blind spots were measured from a distance of 2 meters using a 2mm test object against a dull black screen.

Depth perception was measured using the Howard-Dolman depth perception device. Five trials were taken in each direction for each test, and the average of these ten trials was taken as the subject's score. The variable rod was placed at a different distance from the fixed rod on each trial to reduce the effects of guessing.

The amplitude of accommodation was measured by means of a reduced Snellen chart placed at 33 cm., and the subject was asked to report when one of the small lines blurred so that it could not be read as minus lenses were increased in power before the eyes.

RESULTS

The optometric data were recorded for each test on special data sheets and were compared after the vigil was completed. The results for the tests for each subject are tabulated in Tables 1-4. The data for peripheral vision W, B, R, G are averages of 8 meridians, while the Howard-Dolman (H.D.) error is the average error for 10 trials in mm. Each test series in the tables indicates the results for an additional ten hours without sleep, Series 1 being given just after normal sleep and Series 7 after approximately 60 hours of sleeplessness. These data from 4 subjects do not lend themselves to extended statistical treatment, so the results will be treated in a descriptive manner.

Static Retinoscopy. For two of the subjects, the preliminary and post-tests indicated the same amount of hypermetropia, while the third (Li) showed .25D. less myopia in the post-test. A post-test was not obtained for subject Th. Subsequent measurements verified the finding that there were 3 simple hyperopes and one subject with low myopic astigmatism.

There was no appreciable or consistent change in the astigmatic findings for any of the subjects. Subjects St and Fr showed no astigmatism at any time. Li's astigmatic finding was constant throughout his tests, and .25D. astigmatism was found binocularly for Th in 2 tests, but these tests were not successive. It can be seen, then, that no significant changes were found in astigmatism.

On the other hand, it can be observed from the tables that changes occurred in the spherical measurements for three of the subjects. Fr, however, showed a maximum variation of .25D. during the series and the final test in the experiment was identical with the pre-and post-tests. After 50 hours of sleeplessness, Th showed the same degree of hypermetropia as on the first test, but subsequent to this decreased .50D. in the right and .25D. in the left eye. St, after 50 hours, showed a decrease in hypermetropia of .75D.O.U., but after 60 hours this was only .50D. Li was found to show the greatest change at the end of about 40 hours, after which he was unable to continue. At the 30-hour test he showed an increase in myopia of .75D.O.D. and .50 O.S. and after 40 hours,

TABLE 1

Results of visual tests during a prolonged vigil for subject Fr.

	Pre-	1	2	3	4	5	6	7	Post-
Static O.D.	+1.00	+1.00	+1.00	+0.75	+1.00	+0.75	+0.75	+1.00	+1.00
Static O.S.	+1.00	+1.00	+0.75	+0.75	+1.00	+1.00	+0.75	+1.00	+1.00
Dynamic O.D.	+2.25	+2.00	+2.25	+2.25	+2.50	+1.75	+2.50	+2.50	+2.50
Dynamic O.S.	+2.25	+2.00	+2.00	+2.25	+2.50	+1.75	+2.50	+2.50	+2.50
Phoria 20′	1 ESO	1 ESO	1 ESO	2 ESO	1 ESO	2 ESO	1 ESO	1 ESO	2 EXO
Phoria 13″	3 EXO	4 EXO	3 EXO	4 EXO	4 EXO	9 EXO	2 EXO	7 EXO	ORTHO
Add. 20′	20/12	26/12	22/10	16/6	20/7	14/8	20/9	24/14	24/12
Abd. 20′	8/4	12/5	6/2	6/4	8/4	9/6	6/2	8/4	10/4
Add. 13″	13/15	18/8	20/16	15/3	20/16	16/0	22/12	20/0	22/14
Abd. 13″	17/2	16/6	16/10	16/10	14/12	20/10	16/9	16/8	16/10
Acc. O.D.	5.75	6.25	6.75	6.25	6.25	5.75	6.75	6.00	6.75
Acc. O.S.	6.25	6.75	6.75	6.50	6.50	6.25	6.75	6.25	6.75
V.A., O.D.	....	20/20-4	20/20-2	20/20	20/20-1	20/20	20/20-1	20/20-2	.....
V.A., O.S.	....	20/20-4	20/20-2	20/20-2	20/20-1	20/20	20/20	20/20	.....
Av., W	55.4	59.5	51.0	46.5	50.1	47.5	57.0	49.4	53.3
B	40.3	37.1	36.4	41.1	40.0	40.5	42.1	38.4	47.4
R	30.6	25.9	26.3	29.0	31.0	30.9	29.8	30.5	27.6
G	14.0	13.4	12.6	17.9	16.3	15.5	17.6	20.0	18.5
H.D., mm.	....	8.6	8.0	16.9	9.5	23.9	14.9	21.5	...

TABLE 2

Results of visual tests during a prolonged vigil for subject St.

	Pre-	1	2	3	4	5	6	7	Post-
Static O.D.	+1.00	+1.00	+1.00	+1.00	+.25	+.75	+.25	+.50	+1.00
Static O.S.	+1.00	+1.00	+1.00	+1.00	+.50	+.75	+.25	+.50	+1.00
Dynamic O.D.	+2.00	+2.50	+2.25	+2.50	+2.00	+2.00	+2.00	+2.25	+2.00
Dynamic O.S.	+2.00	+2.50	+2.25	+2.50	+2.25	+2.00	+2.00	+2.25	+2.00
Phoria 20′	1 ESO	1 ESO	1 ESO	1 ESO	3 ESO	Ortho.	Ortho.	1 EXO	2 ESO
Phoria 13″	1 ESO	2 EXO	Ortho.	1 ESO	3 ESO	11 EXO	2 EXO	4 EXO	Ortho.
Add. 20′	24/16	48/44	38/38	40/40	36/36	40/40	40/40	40/40	40/40
Abd. 20′	14/5	12/6	13/6	12/8	14/8	10/6	10/8	8/1	12/8
Add. 13″	32/10	32/23	44/40+	40/40+	40/40+	40/40+	40/40+	40/38	40/40+
Abd. 13″	22/8	19/14	20/18	20/14	24/18	20/14	28/13	22/14	20/18
Acc., O.D.	5.75	6.25	6.75	6.25	6.25	5.75	6.75	6.00	6.75
Acc., O.S.	6.25	6.75	6.75	6.50	6.50	6.25	6.75	6.25	6.75
V.A., O.D.	20/20	20/30	20/20-2	20/20	20/20	20/20	20/20	20/20-1	. . .
V.A., O.S.	20/20	20/30	20/20-1	20/20-2	20/20	20/20-2	20/20	20/20	. . .
Av., W.	56.3	57.8	54.8	50.1	50.0	50.9	49.3	49.3	61.9
B	40.9	40.3	38.0	34.5	37.8	34.5	31.3	30.9	41.0
R	35.9	34.0	33.3	29.6	27.9	23.4	21.3	21.8	31.0
G	23.3	20.1	16.9	15.5	16.9	14.4	14.5	14.6	19.6
H.D., mm.	14.4	41.2	11.3	7.4	26.2	10.5	6.4	5.5	. . .

TABLE 3

Results of visual tests during a prolonged vigil for subject Th.

	1	2	3	4	5	6	7
Static O.D.	+.75	+ .75	+1.00	+ .75	+ .50+.25x90	+ .75	+ .25+.25x90
O.S.	+.75+.25x90	+1.00	+1.00	+1.00	+ .50+.25x90	+ .75	+ .50+.25x90
Dynamic O.D.	+2.00	+2.00	+2.25	+2.25	+1.50+.25x90	+2.25	+1.75+.25x90
O.S.	+2.00	+2.25	+2.25	+2.25	+1.50+.25x90	+2.25	+2.00+.25x90
Phoria 20′	2 EXO	2 EXO	3 EXO	4 EXO	4 EXO	4 EXO	1 EXO
Phoira 13″	8 EXO	10 EXO	10 EXO	10 EXO	10 EXO	10 EXO	10 EXO
Add. 20′	36/6	30/0	27/-2	25/0	20/7	31/0	16/6
Abd. 20′	16/8	16/6	12/10	14/5	16/8	14/8	14/3
Add. 13″	26/3	23/12	24/6	19/8	20/12	24/7	16/6
Abd. 13″	32/14	28/10	36/20	32/12	22/12	28/17	24/14
Acc., O.D.	+7.00	8.00	6.75	6.50	6.25	7.00	6.00
Acc., O.S.	7.00	8.00	7.00	6.25	6.25	6.75	6.75
V.A., O.D.	20/20-2	20/20-4	20/20-1	20/20-3	20/20-3	20/20-3	20/20-2
V.A., O.S.	20/20-1	20/20-3	20/20-3	20/20-3	20/20-3	20/20-4	20/20-2
Av., W.	65.4	60.4	60.4	64.3	66.5	54.9	61.8
B	45.1	48.4	46.9	44.9	47.9	36.3	40.5
R	35.5	38.6	33.1	34.0	31.0	26.4	32.6
G	32.6	36.1	28.4	32.2	35.0	26.1	28.6
H.D., mm.	10.4	9.3	21.5	15.8	7.8	13.3	11.0

TABLE 4

Results of visual tests during a prolonged vigil for subject Li.

	Pre-	1	2	3	4	5	Post-
Static	—1.00+.25	— .75+.25	—1.00+.25	— .75+.25	—1.50+.25	—1.75+.25	—0.75+.25
O.D.	x180	x180	x180	x180	x180	x180	x180
Static	—1.00+.25	—1.00+.50	—1.00+.25	—1.00+.25	—1.25+.25	—1.25+.25	—0.75+.25
O.S.	x180	x180	x180	x180	x180	x180	x180
Dynamic	+ .75+.25	+1.00+.50	+.50+.25	+1.00+.25	+ .25x180	+ .25x180	+1.00+.25
O. D.	x180	x180	x180	x180			x180
Dynamic	+ .75+.25	+ .75+.50	+ .50+.25	+ .75+.25	+ .50x180	+ .25+.25	+1.00+.25
O.S.	x180	x180	x180	x180		x180	x180
Phoria 20′	4 EXO	1 EXO	ORTHO.	1 EXO	1 EXO	2 EXO	6 EXO
Phoria 13″	2 EXO	6 EXO	6 EXO	4 EXO	8 EXO	19 EXO	3 EXO
Add. 20′	22/12	15/5	16/12	24/12	18/11	16/8	18/12
Adb. 20′	13/9	10/6	8/6	13/7	9/6	15/13	11/8
Add. 13″	16/8	14/0	16/10	16/8	9/5	-2/-4	12/7
Abd. 13″	22/12	22/12	15/9	20/13	15/10	Diplopia 28/12	28/18
Acc., O.D.	12.50	13.0	12.75	12.00	13.00	6.5	13.00
Acc., O.S.	12.25	12.5	13.0	12.25	13.5	7.5	13.00
V.A., O.D.	....	20/30	20/40-4	20/40-1	20/50	20/40-3	....
V.A., O.S.	...	20/30	20/40-1	20/40-2	20/40-2	20/40	....
Av., W	67.1	59.5	60.9	57.5	52.5	40.6	55.0
B	45.9	39.8	38.1	37.0	37.8	39.4	36.5
R	41.9	33.5	31.9	26.6	29.5	27.6	31.4
G	27.1	21.9	21.6	17.4	17.4	16.5	18.1
H.D., mm.	....	69.5	70.0	52.5	41.0	66.0	...

1.00D.O.D. and .50D.O.S. Normal sleep caused the test results to return to the original magnitude. These results may be summarized as follows: One subject showed no change in ametropia as indicated by static retinoscopy, 2 subjects showed a small tendency to decrease in hyperopia, while one subject showed a marked increase in myopia.

Dynamic Retinoscopy. There was no consistent change shown in this test for the three hyperopes either in spherical or cylindrical findings. The maximum variation throughout the tests was .50D. and these variations were measured from the highest to the lowest finding. On the other hand, the one myope, Li, showed a consistent change beginning at the end of 30 hours and continuing through the 40-hour test, after which he did not continue. This change amounted to a decrease of .75D. in the spherical measurement, but there was no change in the cylindrical finding. The measurement returned to "normal" after he had a period of sleep. These findings indicate that there was no appreciable change in the dynamic skiametry measurements for the hyperopes and a small but consistent decrease for the one myope.

Heterophoria. There was no significant change in the measurements of heterophoria at 20 feet during the vigil. Fr showed a maximum variation of 1△ throughout the series; Th and St showed a maximum variation (highest to lowest finding) of 3△, and these variations were part above and part below the preliminary finding. Li's findings showed more variation from the preliminary measurement (4△) but after the first experimental test, which indicated 1△ exophoria, the maximum variation was 1△. These results show without doubt that there was no consistent change in heterophoria measured at 20 feet.

The measurements of heterophoria at the near point, on the other hand, showed certain definite changes. Th's 10△ exophoria remained the same throughout the series. However, the other three subjects showed definite changes in increased exophoria. St showed considerable variation through the series varying from 3△ exophoria to 11△ exophoria. The maximum exophoria occurred after 40 hours, but this dropped to 4△ exophoria after 60 hours and returned to orthophoria in the post-test. Li and Fr showed a definite increase in exophoria late in the series. Li ranged from his preliminary test of 2△ exophoria to 19△ exophoria at the end of 40 hours, while Fr changed from 3△ exophoria to 9△ exophoria after 40 hours and 7△ after 65 hours. These findings indicate a tendency to greater exophoria at the near point during a prolonged vigil.

Ductions. The measurements of adduction and abduction showed highly variable results. There is some evidence of the possibility that practice may have influenced these results as indicated by increases in the measurements during the early tests. The findings were also complicated by the fact that at certain times there would be an increase in one measure and a decrease in another.

St showed the least change in ductions. His adductive measurements increased to the maximum measured, 40/40△ for both distant and near measurements. There was a maximum variation of 4△ from the "normal" measurements with but one exception. That was a decrease to 8/1△ for abduction at 20 feet during the 60-hour test.

The other three subjects showed considerable variation. Fr showed no change in abduction greater than 2△ for "break" or recovery at either distance. His change in adduction was not consistent. At 20 feet the 60-hour measure was slightly greater than the preliminary or post-tests. However, there was evidence periodically that there was at least a temporary reduction in adduction. At 20 hours, adduction was reduced to 16/6 (20 feet) and 15/3 (13 in.); at 40 hours 14/8 and 16/0. The remaining tests at 20 feet were within 3△ of "normal," but at the near point at 60 hours the adduction was 20/0.

Th exhibited changes similar to Fr but to a somewhat lesser degree; however, the changes were only in the diplopia point. The final measurement (60 hours) showed a decrease of 55% at 20 feet and 45% at the near point.

Li's measurements varied up and down from the "normal." His adduction at 20 feet decreased only from 22/12△ to 16/8△, but at the near point he saw double and required 2△ base-in prism to see singly.

Amplitude of Accommodation. For all of the four subjects the amplitude of accommodation was less on the final experimental test than for the pre-tests or post-tests. However, like the duction tests, a considerable amount of variation occurred. Practice with the test also appeared as a factor here, as shown by the fact that the three subjects taking the pre-tests and post-tests all showed a greater amplitude on the test after a normal sleeping period. Subjects Fr and Li showed an increase of .75D. in one eye and .50D. in the other, while St showed an increase of 1.75D. in one eye and 1.25D. in the other.

Because of the practice effects the post-test will be considered "normal" here except for Th, who did not take this test. Fr showed a de-

crease of .75D.O.D. and .50D. O.S. although the minimum occurred at 40 hours with a loss of 1.00D. O.D. and 0.50D. O.S. St showed a minimum finding at 60 hours with a loss of 1.75D. O.D. and 1.50 D. O.S.: Th showed a loss at 60 hours of 1.00D. O.D. and .25D. O.S.

The greatest loss was found with Li where there was a reduction of 7.5D. O.D. and 5.5D. O. S.: this test was taken just prior to the time he was forced to give up and when there were marked subjective symptoms of fatigue. However, 10 hours earlier when he was also very tired, the loss was nil.

These data indicate a definite though irregular tendency for the amplitude of accommodation to decrease during a prolonged vigil. This decrease occurred beginning after 40 hours of loss of sleep and continued through the 60-hour test with some variation during the 50-hour test.

Visual Acuity. The visual acuity, as measured by the Landolt split ring test, showed no significant change for the three hyperopes. None of the three showed a variation of more than 2 symbols missed in the 20/20 line during the experimental series. For these three subjects any changes in visual acuity were less than could be measured by the usual letter test and corroborate Cooperman's (6) earlier findings. On the other hand, the myope showed certain changes in acuity. His acuity measurement decreased to O.D. 20/50, O.S. 20/40-2 at 30 hours and increased to O.D. 20/40-3, O.S. 20/40 at the 40-hour test. This change was small when compared with the decrease in other measures, for example the decrease in accommodation.

Peripheral Vision. When the data for the group as a whole were compared in respect to measurements of peripheral vision, there was a general tendency to decrement when the 60-hour test was compared with the post-test, although Li showed an increase in blue (8%) and Fr showed an increase in both red (10%) and green (8%). In spite of these increases the average decrement at the 60-hour test was: B-11.5% (5.2°), R-10.0% (3.3°), G-9.5% (2.3°), and W-14.75% (8.6°). St's fields decreased in size uniformly throughout the vigil and showed the greatest decrement at 60 hours, i.e. B-25% (10.2°), R-30% (9.2°), G-25% (5.0°), and W-20% (12.6°). Th showed nearly as great a decrement at the 50-hour test. His decrements during this test were: B-20.0% (9.0°), R-25.8% (9.1°), G-18.8% (6.5°), and W-16.0% (10.5°), but there was a uniform increase in the size of the fields during the last test. These data seem to indicate that after 40 hours there is a small decrement in visual fields, on the average, but also there appear to

be times when there are marked restrictions in the visual fields; however, the restriction was not uniform for all colors in any test.

The data were also examined to determine any changes in the overlapping of the fields for color. All of the subjects gave overlapping of red over blue in one or two meridians (never more than 2) during three tests while with Li it occurred during 5 of the 9 tests. However, 60% of the time there was overlapping in but one meridian. It is important to note that approximately 2/3 of these overlappings occurred during the first three tests so that the overlapping could not be considered significant either as to consistency or amount.

There was even less overlapping of green over red. St and Li showed no overlapping of green over red at any time, while Fr showed an overlapping in one meridian during one test (50-hour), but there was no overlapping on the 60-hour test. The green overlapped the red in at least one meridian (variation 1-5 meridians) for every test of Th. However, there was considerable variation during the series and no definite tendency toward an increase or decrease. These data indicate that there is no uniform change in the overlapping of the visual fields during a prolonged vigil.

Measurements of the blind spots were not made accurately enough to permit quantitative comparisons. However, it was apparent that there were no marked changes exhibited under the test conditions which are designed to show rather small changes in the extent of the blind spot.

Depth Perception. The results of the Howard-Dolman test were uniformly irregular, and the variations themselves were small. Only one subject, Fr, showed a uniform tendency to increase, the final error being 2.5 times the error on the first two tests. The average error increased from 0.86 cm. to 2.15 cm. at the 60-hour test and was as high as 2.39 cm. at 40 hours.

On the other hand, two of the subjects, Li and St, actually made a smaller error on the last three trials than on the first three tests, although the improvement in both cases was less than 1 cm. Th showed considerable variation. The average error was 1.04 cm. on the first, up to 2.15 after 20 hours, down to 1.33 at 50 hours, and 1.10 cm. on the final test.

These data indicate that there is no uniform loss of depth perception during a prolonged period of sleeplessness. However, one of the 4 subjects did show a consistent loss during the vigil.

Although these data appear largely negative when considered indi-

vidually, it is worth noting that low scores or scores which deviated widely from the "normal" or control scores occurred much more frequently during the last half of the vigil. The number of these "deviatory" scores was determined for the first 3 testing periods and the last three tests, and it was found that there were approximately 4.5 times as many of these "deviatory" scores during and after the 40-hour series. The post-test in each case showed a recovery to the "normal." It can be seen from these data that a decrement in performance certainly occurred, but that it was far from regular throughout a whole series of tests, as far as the test results were concerned. It is also significant that similar changes occurred earlier and though they were much less frequent they were occasionally as large, in one or two cases even larger. These results have practical implications in routine office testing where fatigue is being considered.

Discussion

From the data presented, it is apparent that there was no consistent reduction or deviation in astigmatism, depth perception, or phoria and ductions at 20 feet. There was a slight decrease in dynamic skiametry (Li), a slight decrease in adduction at the near point (3 subjects), a slight decrease in visual acuity (1 subject), and a slight reduction in the visual fields for 4 colors (all subjects). More pronounced changes occurred in the following: an increase in myopia (Li) and decrease in hyperopia (St, Th); an increase in exophoria at the near point (3 subjects), and a decrease in accommodation for all subjects, the reduction being 46% for Li. It is also significant that the greatest number of measurements which deviated from the "norm" occurred after the 30-hour test.

In general these results, like those of other similar experiments, are largely negative in spite of the fact that the symptoms reported by the subjects were very definitely positive. These results may seem at variance with what would be expected, but they are closely comparable to findings in clinical work when a patient reports marked visual symptoms, and the routine optometric tests may show only slight deviations from the "normal." They also show the importance of regular periodic tests in studying fatigue, because a beginning and end test alone have very limited meaning.

One of the more important reasons for the negative results is that routine optometric tests must be short and the patient is able to compensate for a reduction in accommodation and ductions, for example, and when this is added to a universal desire to make a good showing in the

test, to say nothing of occasional outright concealment of deficiencies, it becomes additionally important. A corollary of this is that no optometric tests have been designed to test for what Bills calls "blocking" in mental work, and hence it is possible for a patient to make a good score on a test, while immediately following he might have a low score if tested again. Although it is true that there is no direct evidence from these tests that ocular fatigue shows "blocks" that are similar to those found in mental fatigue, there is considerable evidence that it is true. It is apparent from the data that the subjects are not low on all tests at one session. The variability was temporary as shown by recovery on subsequent tests. At one period the accommodation may be low and on the next it will increase, but the ductions may be down. This may be due to "blocks" occurring during the testing process. It is important also that these deviatory responses increased significantly after 30 hours, which was similar to the increase in "blocks" in addition, and subtraction, and color naming for the same subjects (13). Berens' (2) results for accommodation also indicate that ocular fatigue is not directly comparable to physiological fatigue. Their results support the theory that ocular fatigue shows characteristics of mental fatigue.

These results are similar to those of Kurtz (10) and have very practical significance in office practice. Much has been said about the importance of "fatigue," "fatigue patterns," etc., but few tests are adequate to give a satisfactory measure of "fatigue." One author has gone so far as to say that the term "fatigue" should be discarded because our methods of measuring it are inadequate. The present writers are inclined to agree with this point of view unless adequate methods are devised to measure "fatigue." If the results of "fatigue" are to be adequately measured, the testing procedures must involve the following procedures:

1. The test should be of sufficient length to reduce the effect of compensation.

2. Where possible, the test should be constructed to make compensation difficult or impossible.

3. The tests should be repeated where that is practical.

4. Tests which would readily show "blocks" should be devised for practical office testing.

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HETEROPHORIA AND ANISEIKONIA*

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A possible correlation between heterophoria and aniseikonia provides food for much speculation, and while, as will be pointed out, no specific relationship can as yet be demonstrated, there are several important aspects to the problem that deserve consideration. I wish to discuss briefly some of these aspects from clinical experience, and will cite case reports to illustrate various points.

Heterophoria is that condition in which the visual axes of the two eyes tend to depart from parallelism.† This tendency can be elicited, and converted into an actuality, if fusion is suspended, viz, by means of one-sided occlusion, the Maddox rod, dark red glass, prisms, etc.

Aniseikonia[1] is a term of more recent origin and is defined as that condition in which there is a relative difference in the size or shape of the ocular image of one eye as compared with the ocular image of the other eye.

The symptoms presented by patients having heterophoria or aniseikonia are, in general, similar enough to make impractical even a tentative diagnosis of *one* or the *other* on the basis of the symptoms only. Headaches, fatigue, and occasional diplopia are reported most frequently by those having either heterophoria or aniseikonia.

It should be recognized that individuals vary widely in subjective reactions to the same objective causes. You are acquainted with that class of patients with more or less severe symptoms which is relieved entirely by the correction of a moderate refractive error, phoria, or aniseikonia,

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†With the exception of cyclophoria, in which it is the corresponding retinal meridians which deviate from parallelism rather than the visual axes.

whereas, other individuals with the same or even greater error do not complain of any symptoms whatever. The patient who is afflicted with numerous and severe subjective symptoms but who presents relatively toms and anomalies, there is, nevertheless, the patent necessity for the

Even a mild neurosis has serious potentialities, and in some cases one unwittingly enters a "vicious circle" which leads to the development of a major neurosis. There is, for instance, the picture of a man who, initially, is only slightly anti-social, due, perhaps, to new environment or change of interest and values, who, in his spare time takes recourse to reading or to some hobby which favors his introversive nature, but which coincidently, usually involves the use of his eyes which have not bothered him previously, despite a slight error of refraction (let us postulate). The increased use of his eyes, although not changing the anatomical structure, begins to give him a few somatic symptoms which cause some worry and make him neurotic. He is concerned over his symptoms, his eyes, his job, and often seeks refuge in enlarging his symptoms so as to rationalize his peculiarities. This type of individual often responds to a correction which would mean little to another person. Culpin[2], for example, writes that the sensitivity of a neurotic is many times that of a normal person.

The results of a study[3] on the 1940 Freshman Class of Dartmouth College show that only about two-thirds of those reporting symptoms had any significant eye defect, and there was no definite correlation between symptoms and magnitude of eye defects. Four of the most common symptoms reported in this group were: fatigue in reading; headaches; nervousness; and car-train-sea-sickness. Breaking down the group in relation to kind and amount of defect did not show that one could distinguish those who should have symptoms on account of their eye errors nor, vice versa, those who should have eye errors because of their symptoms.

Despite, however, the statistical lack of agreement between sympsmall objective anomalies is very often considered neurasthenic or psychoneurotic.

practitioner to view with utmost concern and unbiased judgment the symptoms of his individual patients. It is primarily because of subjective symptoms that people come to the eye specialist for consultation and therapy. The patient is not satisfied, does not consider himself "cured" unless all, or at least part, of his symptoms are relieved; he will, of course,

not be satisfied with the bland assurance that his trouble is not due to his eyes. We are not justified in giving that assurance before we have eliminated all possibilities. If we could set the clock of time back about fifty years, when knowledge of the presence and correction of astigmatism was not so widespread as it is now, would we not refer, unjustly, to many people as neurotics because they did not obtain the relief expected from the spherical correction given them?

The conscientious practitioner will recall patients, known colloquially as "grief cases," that fail to respond to a correction of refraction, despite the inclusion of prisms for a possible muscular imbalance, even despite the most assiduous orthoptics, and also despite the negative findings of a competent physician, dentist, and neurologist. In general, I think it safe to recognize that the refraction cannot be suspected as much as the possible presence of a significant heterophoria or aniseikonia because, as most of us will agree, our strong point is our refracting ability.

Relative to heterophoria, there may be some factors which lead us to erroneous conclusions, as it is commonly recognized that the power of the fusion faculty varies greatly in different individuals, and, in some cases may be able to keep the true position of rest of the eyes concealed completely: on the other hand, the manifestations of a significant imbalance may be elicited by a technique which indulges the expression of a certain specific deviation. For example:

Case of D.E.S., No. 5741, age 47.

Complained of severe headaches and asthenopia for any use of the eyes to the extent of necessitating giving up occupation. Refractive error of moderate hyperopic astigmatism was well corrected and repeatedly verified by competent men. Usual phoria tests taken over a period of years failed to show anything significant: the findings varied between ortho. and 2△exo. for distance and 4 to 7△exo. for near. By occluding one eye and then the other for about a week (Marlow's prolonged occlusion test)[4] a hitherto latent divergence of about 25△ was discovered which, being partially corrected by 8△B. in O.U., gave complete relief. This case, then, was one whose fusional ability was of necessity so strong (to overcome the true exo. position of rest) that with the usual phoria test nothing significant could be found; it required the suspension of the fusion apparatus for a considerable period to elicit the true position of rest of the eyes.

Another type often interpreted wrongly, but more often overlooked

completely, is that of alternating or dissociated hyperphoria which, it has been stated,[5] occurs in more than 41 per cent of cases of heterophoria. The following case will illustrate the phenomena:

Case of H. A., No. 2703, school girl, age 16.

Complained of frontal headaches and difficulty in reading. Myopic astigmatism was well corrected, but the tests for muscle balance disclosed that when the red glass was put over the right eye and the patient directed to fixate a white light on a tangent scale, the right eye image was reported down and to the left, as in the case of exophoria combined with *right* hyperphoria; but when the red glass was put over the left eye and the test repeated, the patient saw the red light to the right and down, that is, exophoria and *left* hyperphoria. Our findings were, with the red glass over the right eye, 8△exo.⌒8△R.H., and with the red glass over the left eye, 8△exo.⌒12△L.H. This, then, is a case of double or alternating hyperphoria; each eye when covered turns upward so that on testing the projected images there will be found first a right hyperphoria, then a left hyperphoria, depending upon whether the right eye or the left is fixating.

The more or less common practice of covering one eye only, usually the right eye, has resulted in some of these cases of dissociated hyperphoria being diagnosed and treated erroneously as right hyperphorias. I can recall one case wherein a prism correction of 7△ base down on O.D. was given for a supposed right hyperphoria. It was definitely learned that the patient had been tested with the usual method of the Maddox rod on the right eye only. By putting the red glass over the left eye, we discovered instead of a right hyperphoria, a left hyperphoria, and, by removing the prism correction, the patient was much more comfortable.

These examples show the need, in all phoria tests, of covering not only the right eye but the left eye as well; also it must be remembered that the same holds true in using the prolonged occlusion test, each eye must be alternately covered.

This condition—called alternating or dissociated hyperphoria—of finding a right hyperphoria when the right eye is covered and a left hyperphoria when the left eye is covered, has been carefully studied by Dr. A. Bielschowsky[6] and you are referred to his writings for further study. Needless to say, a prismatic correction or an operation, instituted because of the phoria finding on one eye must be placed in the category of an accidental therapy even if it does give relief only fortuitously. The interven-

tion of prisms or surgery, in cases of dissociated vertical divergence is contra-indicated or at least useless because alternating or dissociated hyperphoria is purely a peculiar kind of innervation anomaly, differing from concomitant hyperphoria in that it is caused neither by mechanical factors nor by a paresis, but by intermittent and alternating excitations of the two antagonistic vertical motor centers. Attention should be directed to other possible causes, such as any coexisting horizontal imbalance, or any uncorrected aniseikonia, because the fusion faculty may prevent the tendency to dissociated vertical deviation from becoming manifest when it has been relieved of such burdens as an abnormal position of rest of the eyes or an incongruity in the relative size of the ocular images.

If heterophoria is combined with aniseikonia the subjective symptoms may be due either to the heterophoria, the aniseikonia or a combination of both. I wish now to present a case in which the patient's trouble was relieved by the correction of the relative difference in the size of the ocular images after attempts with dioptric and prismatic corrections had been tried with negative results.

Case of A. C. C., No. 3475, age 19, comptometer operator.

First seen on May 24, 1937, wearing for near only +0.50 sph. O.U. Complained of dizziness, periodic diplopia, and asthenopia, especially for close work, to such an extent that she had to give up her position. The referring doctor had found as much as 50 arc degrees of esophoria for distance and 40 arc degrees for near. At times, however, her eyes were straight objectively and some stereopsis could be determined, but a tendency to suppress the image of the right eye was present. Prisms base out were tried but rejected. Her specialist, in view of his findings, was disposed to consider a neurotic basis for the dizziness. Our refraction tests disclosed emmetropia O.U. The muscle tests showed a varying spasm of convergence, the average esophoria being about 9 arc degrees for distance and 14 arc degrees for near. Test for aniseikonia gave R. 1.75%x90: L. 1.00%x180. That is, the right ocular image was relatively smaller than the left by 1.75% in the horizontal meridian, but larger in the vertical meridian to the extent of 1.00%. The patient was loaned a pair of glasses to correct for the image size difference only, and she returned two months later for a recheck and reported no dizziness, no discomfort for reading, and no diplopia. Rechecking the patient on the ophthalmo-eikonometer gave the same findings as previously, but it was noticed that her fusion was much better. In fact, in the phoria test orthophoria was found at first, but as the eyes were dissociated for a few minutes, the original

esophoria became evident. A third recheck six months later again showed the same findings: the patient was still comfortable and had returned to work.

This case, then, is one presenting heterophoria which was not influenced by a refractive or prismatic correction, but when the existing aniseikonia was corrected the fusion faculty was able to cope with the esophoric position of rest. The size correction, indeed, did not change the phoria per se, but removed one of the obstacles to binocular single vision and so helped the fusion faculty to overcome the tendency to abnormal convergence.

When we consider that the extra-ocular muscles are rather gross structures capable themselves of executing considerable versions of the eyes, it must cause one to wonder why the muscles themselves cannot easily overcome a deviation of say 10°. Indeed, the muscles are powerful enough to overcome many deviations that are often encountered in practice, but it must be remembered that the functioning of the extra-ocular muscles depends on the efficacy of the different motor centers controlling the voluntary and the fusional movements. In a case of convergence paralysis the internal rectus muscles, for instance, may bring about maximal adversion in parallel (lateroversion) movement, while they are unable to react to convergence impulses. If the centers for fusion movements are weakened or are not functioning at all they will be unable to correct the slightest displacement of the retinal images of one eye by a corresponding change of the position of the eyes relative to each other. The resulting double images will be fused only when by means of prisms or the haploscope.* the images are shifted from disparate to corresponding retinal areas. You will recall cases of heterophorias with fusion and depth perception, while some cases with manifest squint will not fuse even when the two images are brought from disparate to corresponding retinal points by prisms or the haploscope. If one puts prisms before the eyes the two images may be said to approach each other and then, just when they are about to touch each other and merge, they "hop over." There are two anomalies which account for this: one is abnormal retinal (sensorial) correspondence, to which I will refer later, and the other is purely an antipathy to fusion called "horror fusionis."

A most interesting case of "horror fusionis" was published by Dr. Bielschowsky[7]: in fact, it was this particular case and the role played

*A haploscope is essentially a reflecting stereoscope.

by aniseikonia in the etiology of strabismus which attracted Dr. Bielschowsky's attention to Dartmouth. This case is summarized as follows:

"The patient, (Mr. V.), had acquired convergent squint in 1916, when he was seven years old. In 1922 both eyes were operated on. In 1933 diplopia combined with severe headaches, insomnia, and other troubles set in. Neither by three further operations nor by fusion exercises could diplopia be removed. The very slight but unsteady deviation, due to a paretic post-operative weakness of almost all the muscles of the right eye, was composed of a lateral, a vertical, and a rotary component. Besides, spasms, occurring at irregular intervals, frequently altered the position of the eyes. Fusion could be obtained neither by prisms nor the haploscope. The eyes seemed to shun any position in which outlying objects would be imaged on corresponding points, preventing it by almost continually changing their position relative to each other. Finally, a considerable difference in the relative size of the ocular images (L. 11% overall ⌣ 4.5% x150) was ascertained, the correction of which by size lenses helped the patient to get binocular single vision, with depth perception and fusional amplitude. Since then the patient has been entirely comfortable for over three years."

Illustrating further the effects of aniseikonia on the fusional ability is the following case:

Case of G. I. W., No. 1375, college student, age 21.

First seen April 7, 1936, wearing for past 2 years O.U., Plano ⌣ 3½ △B. in. Normal vision each eye. Complained of periodic crossed diplopia and eye fatigue for all use of the eyes, but more pronounced for reading. Had taken two 3 months series of orthoptics without relief. Refraction tests showed emmetropia to a slight myopia (—0.25 D. sph.). For distance there was 16△ exophoria, and for near 20△ exophoria. Normal retinal correspondence was determined. A size difference of 3.00% overall was found, the right image being relatively smaller than the left. This correction for aniseikonia was loaned to the patient to wear in lieu of his prismatic correction, and he was asked to report in a month, which he did, stating that he found the aniseikonic correction better than the prismatic one; he had had less headaches, could read longer, and had not seen double once. He was very definite that the size correction was better than the prisms.

It has been stated[8] that possibly aniseikonic patients are particularly susceptible to suggestion, and that the relief they report is due to the

impressive and lengthy tests, to a new type of correction, and other psychological factors.

Therefore, to test our patient's credulity, we decided to try, without his knowledge, three different corrections, but as a result the patient stated that the 3% correction (the really correct one) was best.

It is of interest to note that the amount of phoria was the same with, and without the size correction. The apparent reduction of phorias noticed in some cases that have been given dioptric or aniseikonic corrections as well as orthoptics, can be reconciled only by the assumption that the fusion faculty has been strengthened and is thereby able to conceal the true position of rest of the eyes; this position can be revealed only by a sufficiently long dissociation of the eyes.

Another case of interest in the heterophoria—aniseikonia group is that which follows:

Case of F. L., No. 565, age 37, an engineer.

First seen in 1934 wearing 5△B. in O.U. for past 2 years. First Rx at age of 9. Orthoptics at various times with no lasting effect. Symptoms of intermittent periods of diplopia and general asthenopia in use of eyes for reading, movies, driving, etc. His refraction was insignificant (+25+25×90 O.U.); normal vision each eye. His phoria averaged 20△exo. for distance, and about 30△exo. for near. A 1.25%×90 size difference was found the right ocular image being relatively smaller than the left in the horizontal meridian. He was given in 1934, R. 1.25% mag.×90; L. Plano, with no prisms and he reported comfort with no diplopia in the use of his eyes. He stated the aniseikonic correction was more comfortable than the 5△B. in O.U. This patient reported this summer (1938), having worn the aniseikonic correction for four years, that he had been very comfortable, could use his eyes as much as he liked. Rechecking the phoria still showed the rather high exophoria, the same as before, so we may be sure that we did not change the phoria by giving an aniseikonic correction, but we did change his ability to cope with his exophoria.

It does not follow, of course, that aniseikonia, if associated with heterophoria, is always the main or only cause of the patient's trouble, and that the ideal correction for the muscle imbalance is iseikonic lenses rather than prisms. In contra-distinction to the cases previously mentioned, there are others in which the prismatic correction of the phoria gives relief. For example:

Case of A. F. S., No. 4549, college student, age 19.

First seen November 3, 1937. Complained of general asthenopia, never noticed double vision but closed one eye when particularly tired. Wearing R. +0.75 cyl. × 3; L. +0.50 cyl. × 180, giving 20/40 vision, each eye. Our refraction showed: R. —0.25 sph. +1.00 × 180 20/20; L. —0.50 sph. +1.00 × 180 20/20. Phorias were for distance 0 to 1△ exo. ⌒ to 6△ left hyperphoria; and for near, 1 to 2△ exo. ⌒ 5 to 9△ left hyperphoria. The tests for aniseikonia showed the vertical fixation disparity corresponding to the left hyperphoria, and, not correcting the phoria, a 4% size difference was found. However, correcting the phoria with 3△B. up on the O.D., and 3△B. down on the O.S., no size difference could be ascertained. It was noted that the patient had excellent fusional amplitude; he could overcome as much as 5△ base down over the O.D. or base up over the O.S., and more than twice that amount in the opposite direction. It would seem that if this patient could maintain fusion, no image size difference would be present, but when he allowed his vertical imbalance to become manifest, a significant size difference was present. This may explain why this patient had such good binocular vision despite his latent vertical imbalance; that is, he had developed a high fusional amplitude to avoid encountering the image size difference present when his eyes diverged.

This theory may be supported by the fact that there are those who have aniseikonia when the phoria is corrected, or reduced, and find no comfort in, and do not react favorably to prisms or orthoptics. It seems that rather than cope with the aniseikonia present in binocular vision they attempt to avoid binocular vision by suppressing one image or by having one eye deviate in order to avoid fusion.

Our patient (A. F. S.) was first given the refractive correction to wear for a month, which he did, and reported that although he could see a little clearer he was no more comfortable and, if anything, reading was a little more difficult. We then added 3△B. up over the O.D., and 3△B. down over the O.S., relative to which he reported the next day that he felt fine, could read for unlimited periods without any discomfort. After a month he reported he enjoyed the glasses very much; the prisms were a great improvement. We again checked the phoria and aniseikonia, and found the same as mentioned previously.

Another interesting case is the following:

Case of L. E. S., No. 3014, boy, age 14.

First seen February 9, 1937, complaining of a small growth on the

lower lid of the right eye; no other symptoms, never wore glasses. The chalazion was removed and the right eye bandaged for three days. When the bandage was removed, the patient complained of diplopia, which he had never experienced previously. There was found a manifest convergent strabismus of 16 to 18 arc degrees; normal retinal correspondence; fusion and depth perception could be given with prisms; refraction showed +4.50 D. sphere O.U. by the retinoscope. Aniseikonia, measured on a special apparatus in which targets for each eye could be swung to indulge the angle of squint, was of a high amount, about 10%. The patient was given plus spheres, base out prisms and orthoptic exercises, and he was rechecked several times with the result that his fusion improved very quickly so that the prisms could be reduced gradually, and finally be removed completely. As his fusional amplitude became restored he began to leave off the plus correction without discomfort maintaining binocular single vision with depth perception. The most interesting feature of this case is that as the fusion faculty became restored the measurements for aniseikonia showed less and less size differences until finally, after about a month, the patient discovered he could go without the plus spheres, anisekonia could no longer be elicited. The convergent strabismus, or at least a high esophoria, could again be brought about by breaking fusion, and when tested with a haploscopic arrangement an increasing amount of aniseikonia could be determined the greater the convergence that was brought about, while in the orthophoric position, no aniseikonia could be found. This suggests that the extra-ocular muscles may play a part in the etiology of aniseikonia. Subsequent tests made a month later (April 10), during which time the patient had not worn any glasses, showed good binocular vision with perfect depth perception, and 20/15 vision each eye. No aniseikonia could again be found in the primary position. Furthermore, the patient had no symptoms whatever, despite his uncorrected refractive error and latent esophoria.

This case is one in which the strong fusion apparatus was able to keep under control a considerable amount of esophoria which, however, was converted into a convergent strabismus when monocular occlusion interrupted his fusion for three days. Concomitant with the strabismic position of the eyes there was a high amount of aniseikonia, but as the patient soon regained binocular vision the aniseikonia gradually disappeared. The non-existence of aniseikonia when single binocular vision was present argues that the speedy restoration of single binocular vision was hastened by this fact; also that when the eyes were in a convergent position

a high amount of aniseikonia was encountered. On the other hand, some patients who have an uncorrected aniseikonia may not be comfortable when their heterophoria has been nullified by prisms or made more latent by fusion exercises; in fact, they seem to be more uncomfortable.

There is some evidence suggesting that if this patient had aniseikonia when he kept his phoria latent, i.e., had fusion, he would have had to cope with such difficulty that he would have "preferred" to adopt a strabismus which would have dispensed with the necessity of attempting to fuse two dissimilar images. The difficulty in those cases taken for orthoptics and in which no progress is made may be that although the extra-ocular muscles could undoubtedly turn the eyes parallel, they resist doing so because an aniseikonia may be present which would be more annoying than would be merely monocular vision. We know of those cases in which there is normal vision in each eye but which have alternating uni-ocular vision periodically. These cases apparently resist all attempts toward binocular single vision. For example, there is the

Case of Mr. L. S., No. 2456, age 21.

First seen November 19, 1936. Complained of fatigue in reading and also some gastric disturbances. There was the history of cross-eyedness in childhood. Wearing +4.50 +0.50 x 90 O.U. No pathological condition could be found and our refraction tests showed substantially the same prescription as he was wearing. However, we discovered that, although his eyes with the glasses on looked perfectly straight, he had no fusion or depth perception, but alternating uni-ocular vision. On the usual phoria test he was very uncertain and said he could not see the red light and the tangent scale at the same time, but saw either one or the other alternately. The cover test disclosed a very small angle of squint, about 3° esotropia, and anomalous retinal correspondence was determined by the double image test, as well as by the after image test[9]. Tests for aniseikonia were difficult due to the abnormal localization of the images of either eye, but after considerable experimentation there was found a 9.00% aniseikonia —the right image being relatively larger than the left in the horizontal meridian. He was given an iseikonic fitover lens to wear over his refractive correction. One month later he returned stating he was not fatigued while reading, and that he felt he was seeing some depth. Our tests now disclosed normal retinal correspondence, fusion, and depth perception. Our last recheck this summer, a year and eight months after we first saw the patient, showed he still had binocular single vision and depth perception.

He had not been given any orthoptics nor prisms but merely the correction for aniseikonia.

The last case I wish to report is interesting because it is so definitely an aniseikonic case, which might have been given considerable orthoptics unnecessarily.

Case of F. H. R., No. 4705, boy, age 10.

Referred to us by an optometrist November 26, 1937. Never wore glasses: no symptoms: but in school it was detected that the vision of his left eye was extremely low. Our tests showed no pathological condition, visual acuity without lenses R. 20/20+; L. 20/400. No binocular vision, suppresses the image of the left eye, no significant muscle imbalance. Refraction showed R. +1.00 D. sph. 20/20+; L. +5.00 D. sph. 20/80—. He was loaned this refraction with an occluder for the right eye. In two weeks the vision of the left eye with glasses was 20/40. There was some fusion with the stereoscope, but no depth perception. In two more weeks the patient returned, having worn the glasses without the occluder; the vision of the left eye had gone back to 20/66 ($\bar{c}$ Rx) and he had experienced some diplopia. Tests for aniseikonia were made and it was found that the right image was relatively smaller than the left to the extent of 3.50% overall. The correction for aniseikonia was added to his refractive correction, and he returned in two months reporting that the glasses with the size added were a big help. He had not worn the occluder nor had any orthoptics since receiving the aniseikonic correction, and he now had normal vision in each eye with good fusion and 100% stereopsis.

In conclusion, I wish to point out by this brief discussion and the few cases presented that the factor of aniseikonia must be considered in dealing with cases of heterophoria and in cases of poor fusion. To be sure, aniseikonia is not responsible for all the trouble in such cases but its incidence in stubborn cases of "horror fusions," one-sided amblyopia, fusional insufficiency, is such as to warrant attention. By confining this paper to heterophoria and aniseikonia it is not implied that aniseikonia should be overlooked in other cases not complicated by a heterophoria or deficient fusion. Previous papers[10] on aniseikonia have treated the importance of this anomaly in cases presenting no significant motor or fusional instability. It might also be mentioned that there seem to be prevalent more acute symptoms in those cases which apparently do not develop partial or complete suppression of one image: it seems probable in some

cases, that as a sort of defense against incurring the difficulty of fusing two slightly unequal images, innervations are adopted which will put the eyes in a strabismic position unfavorable to fusion. Another point that has been noticed is that patients complaining of some discomfort do not achieve maximum relief if an existing aniseikonia remains uncorrected, despite the fact that the heterophoria may be compensated for by prisms or made latent by fusional exercises.

The intention of this paper is:

1. To point out the impossibility of relying solely on subjective symptoms in differentiating heterophoria from aniseikonia.
2. To recommend that more attention be given to the tests for muscle imbalance by recognizing that it is always necessary to test the two eyes alternately for phoria rather than one eye exclusively.
3. To present a few sample cases to illustrate patients needing aniseikonic corrections rather than prisms, and, vice versa, cases needing prisms rather than size correction.
4. To theorize relative to the reasons why some orthoptic cases are not successful and to suggest that possibly aniseikonia plays a part in these cases as well as in the etiology of strabismus.

If some of these points have been of interest and will assist you in your own cases, I feel that much has been accomplished.

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A COMPARISON OF THE BETTS TESTS OF VISUAL SENSATION AND PERCEPTION WITH A STANDARD CLINICAL EXAMINATION*

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INTRODUCTION AND PROBLEM

Optometrists are participating more and more in visual surveys of pupils in the public schools. Since in many of these surveys the Bett's Telebinocular instrument is used, it seems advisable to investigate the correlation of these tests with standard optometric tests.

The present study attempts to determine the relationship between the Betts tests of Visual Efficiency and Sharpness of Image and comparable tests used in the Optometry Clinic at The Ohio State University.

METHOD

Sixty-nine college students were given the Betts Tests of visual efficiency and sharpness of image. The following cards in the DB series were used in conjunction with the regular Keystone Visual Safety Telebinocular equipped with the "A" type of shaft, calibrated for the reading distance, 40 centimeters, and for an infinite distance.

Slide DB1 —binocular visual efficiency.
Slide DB2 —left eye visual efficiency.
Slide DB3 —right eye visual efficiency.
Slide DB7c —sharpness of image at reading distance.
Slide DB7d—sharpness of image at distance.

The administration and scoring of each of the tests listed above followed all the instructions as given by Betts in his manual (1). Each subject was given a score of "passing," "doubtful" or "failing" on each

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of the tests. All of the subjects who wore corrections regularly, also wore them during the administration of the Betts tests.

Each of the sixty-nine subjects were then referred to the Optometry Clinic at Ohio State University for an examination of refractive errors, phorias at distance and near, amplitude of accommodation and visual acuity.

(1)—*Acuity of Vision*

Acuity of vision was measured in the Optometry Clinic by the use of Snellen test letters at 6 meters for each eye separately and binocularly. Credit was given for the smallest line in which one-half or more of the letters were read correctly. All subjects who wore corrections when tested by the Betts tests wore the same corrections during the test for visual acuity. The visual acuity data obtained in the Optometric Clinic were compared with the visual efficiency data obtained with the DB1, DB2, and DB3 cards of the Betts instrument. This comparison is shown in Tables 1 and 2.

As one can see from the Tables, many receiving doubtful or failing

BINOCULAR VISUAL ACUITY

Betts Test	20/15	20/20	20/25	20/30	20/40	20/50	20/65	Total
Pass	34	26	2	1				63
Doubtful		1		1				2
Fail		1	1		1	1		4

MONOCULAR VISUAL ACUITY

Betts Test	20/15	20/20	20/25	20/30	20/40	20/50	20/65	Total
Pass	45	60	6	2	1			114
Doubtful		1	3	1			1	6
Fail		7	3	2	1	2	3	18

TABLES 1 AND 2

scores on the Betts test manifest a visual acuity of 20/20 or better, whereas many of those passing Betts test manifest a visual acuity of less than 20/20.

Those subjects receiving doubtful or failing scores on the Betts test and manifesting a visual acuity of 20/20 or better on the optometric test might be accounted for by assuming that the awareness of the nearness

of the target in the case of Betts test provides a psychological stimulus to accommodation resulting in a pseudo myopia, which would not be present in the optometric test.

The Betts cards DB1, DB2 and DB3 demand the use of 9△ of convergence in fusing the 20/200 visual efficiency target and 7△ of convergence while viewing the 20/10 target. This use of convergence tends to bring accommodation into play and may account for some subjects receiving doubtful or failing scores on the Betts test but showing a visual acuity of 20/20 or better on the optometric test.

Another thing which would account for this type of discrepancy is that in the optometric test the untested eye is occluded, but in Betts test is exposed to the same kind of target as the tested eye except for the absence of the dots. This makes it possible for the vision of the tested eye to be suppressed, giving a low score on visual efficiency, whereas this same eye might manifest a high acuity in the optometric test. However, tests for phorias using the DB8 and DB9 Betts slides were made on each subject and suppression did not manifest itself in any subject in these tests and hence this is probably not a factor in any of the subjects used in this investigation.

It is difficult to account for the subjects who passed Betts test but manifested a visual acuity of less than 20/20, unless one takes this fact as evidence that the Betts test is not a valid method of measuring visual acuity.

(2)—*Sharpness of Image*

The Betts tests for ametropia consisted in the use of cards DB7d at infinity and DB7c at 40 centimeters on the telebinocular bar. The subjects old glasses, if any, were worn.

The optometric data correlated with these tests consisted in the determination of the extent to which the old glasses failed to correct the ametropia. Subjective tests were made on each subject without cycloplegia for spherical and astigmatic errors of refraction, and the net error of refraction over and above that corrected by the old glasses was computed in each case. Inasmuch as the glasses worn by 8 of the subjects were not measured, these subjects had to be omitted in the analysis of the data for this pair of tests.

The net error of refraction and the score of the Betts test for sharpness of image of the 61 subjects are shown in the graph in Fig. 1. Only

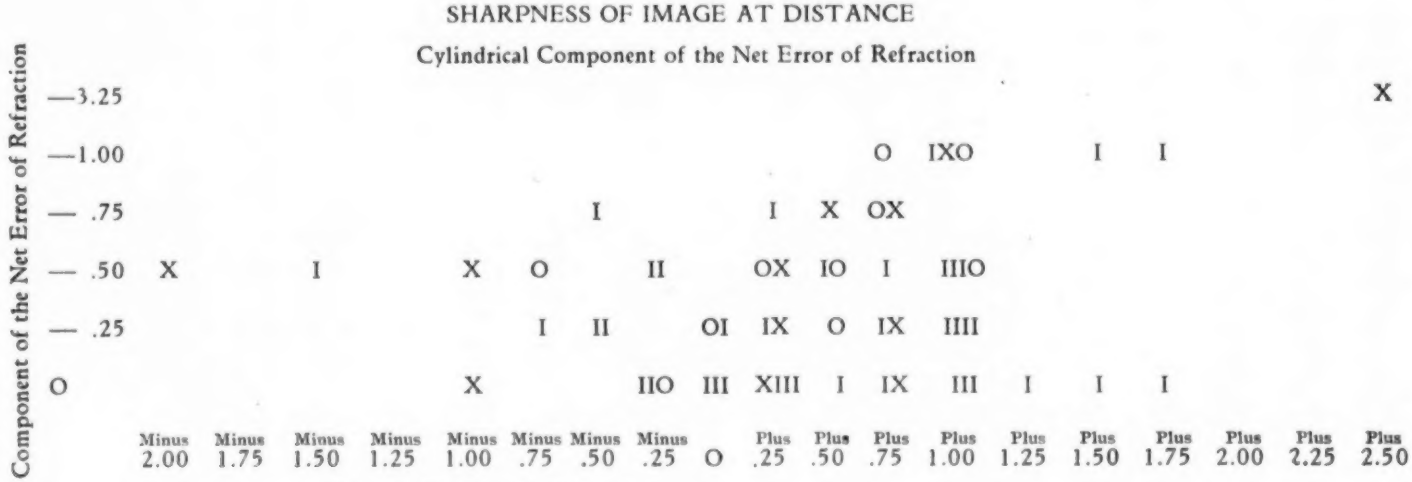

FIG. 1.

Fig. 1—Classification of the Net Lens Corrections of the 61 subjects for the Purpose of Comparison with the Scores on the Betts Test for Sharpness of Image at Distance. The subjects receiving passing, doubtful and failing scores on the Betts test are indicated by vertical lines, circles and crosses respectively.

one error of refraction is specified for each subject. In many cases the net error of refraction was found to be the same in the two eyes and the value indicated on the graph in such cases represents the error which is identical for the two eyes. In cases where a difference in the net error of refraction was found for the two eyes, the value on the graph represents the error of the eye which shows the greater tendency toward myopia or astigmatism. The reason for specifying the refraction of only one eye is that Betts method of scoring provides only one score for each pair of eyes. In case the two eyes make two different scores, the lower of the two is selected as the score for the pair of eyes.

The results obtained on the sharpness of image test at distance must be interpreted from several angles. Of the 20 subjects making doubtful or failing scores in Betts distance test for sharpness of image, 9 showed either simple hyperopia or simple or compound hyperopic astigmatism of less than 1.00 diopter. Several factors need to be considered in attempting to explain doubtful and failing scores in these cases.

In none of the cases used in this investigation has any eye been found to possess amblyopia or a lowered amplitude of accommodation and hence these factors cannot account for any of the doubtful or failing scores. The amplitude of accommodation was determined on each eye by the "push up" method using the .62 M. Jaeger Type for fixation. All subjects manifested an amplitude over 5 diopters, hence each uncorrected hyperope can be regarded as capable of compensating his error of refraction by using his accommodation. The absence of amblyopia in all cases was demonstrated by measuring the visual acuity with the error of refraction corrected. This was found to be 20/20 or better in all eyes.

The nearness of the test object to the subject in Betts test might call into play a certain amount of accommodation over and above that in play during the optometric test for errors of refraction. Furthermore, Betts test is a monocular test and the final check in the optometric test is binocular, and if there is any tendency to esophoria, accommodation which is relaxed in the binocular test for the spherical error of refraction might come into play in the Betts test. Any failure to obtain as much relaxation of accommodation in the Betts test as in the optometric test for errors of refraction might throw subjects with low hyperopia into the doubtful and failing categories in the Betts test. It is interesting to note in this connection that two subjects making failing scores on the Betts tests are simple hyperopes. In such subjects the factor of astimgatism is eliminated and the low score

in Betts test must be attributed to an excess of accommodation. This excessive stimulation of accommodation constitutes a fundamental objection to the use of the stereoscope as a screening out test for errors of refraction.

As can be seen in the graph, some of the subjects with simple or compound hyperopic astigmatism pass Betts test while others receive doubtful and failing scores. As long as a subject with simple or compound hyperopic astigmatism of 1.00 diopter or less is permitted to look first at one set of lines and then another in Betts test, it is possible for him to see them clearly if he uses a different amount of accommodation for each set of lines, but if he is incapable of doing this or simply fails to do it, he sees one or more of the sets of lines blurred and falls in the doubtful or failing category.

Eleven of the subjects passing the Betts test for ametropia at distance possess myopia, or mixed or simple myopic or compound myopic astigmatism. These cases are difficult to explain because some are myopes to such an extent that the errors of refraction appear to be completely incompatible with passing scores on the Betts test. One possible explanation is that these subjects cheat on these tests by failing to report blurredness and are not caught because they can judge the number of lines correctly by virtue of the width or darkness of the blurred image of each set of lines.

In Betts test for sharpness of image at the reading distance only 3 of the subjects received doubtful scores and none received failing scores. The net refractive errors of those receiving doubtful scores are as follows:

Subject A.	O.D.	+3.50 —2.50 × 90
	O.S.	+2.50 —3.25 ×100
Subject B.	O.D.	— .75 — .50 ×120
	O.S.	— .50 — .25 × 30
Subject C.	O.D.	+ .75 —1.00 × 30
	O.S.	+ .25

Subject A would be expected to fail the Betts test because of the high astigmatic error. The other two subjects would not be expected to make doubtful scores on the basis of their errors of refraction because in spite of 1.00 diopter of astigmatism the subject should be able to change his accommodation for the various sets of lines in order to obtain a clear image. This is proved by the fact that numerous other subjects with .75 and 1.00 diopter of astigmatism pass the test. Inability or simple failure

to control the accommodation might account for the doubtful scores in these two cases. Lack of amplitude of accommodation could not account for any of the doubtful scores because in each case the amplitude was above 5 diopters.

(3) *Summary and Conclusions.*

A comparison has been made between the results obtained with Betts tests for visual efficiency and sharpness of image and comparable optometric tests. The results seem to justify the following conclusions:

(1). The use of the stereoscope provides a psychological stimulus to accommodation which in many cases gives an indication of error of refraction which is not found to exist according to optometric tests.

(2). The Betts monocular test for visual efficiency introduces the factor of suppression. This makes it difficult to get a satisfactory comparison between Betts test and the optometric test, but is not necessarily an objection to the test when used for the purpose of screening out persons who need the service of a refractionist, because persons who make a low score because of suppression need the service of a refractionist as much as a person with an error of refraction. However it is hardly justifiable to complicate a screening out test to such an extent that it is impossible to standardize it in terms of the more fundamental tests of the visual functions. Special slides are already included in the DB series for testing suppression and if these cannot be regarded adequate, other slides can be prepared which do not combine the problem of suppression with visual acuity.

(3). The Betts test introduces binocular fixation in the monocular test with convergence varying from 9△ for a visual efficiency of 20/200 to 7△ for a visual efficiency of 20/10. This tends to bring into play convergent-accommodation. The same amount of convergence is required in the binocular visual efficiency test. A monocular test for visual efficiency could be obtained by occluding one eye at a time while using the DB1 slide. Such a procedure would be more amenable to comparison with customary methods of measuring monocular visual acuity in an optometric examination.

(4). The Betts Test of visual efficiency gives in many cases a higher score than indicated in the optometric test which is probable evidence that Betts test is not a valid measure of visual efficiency. A slide with reduced Snellen letters would therefore be subject to less objection.

(5). The Betts sharpness of image test is designed to permit dif-

ferent degrees of accommodation for examining the various sets of lines. This makes it possible for many simple and compound hyperopes to see all the lines clearly, who would fail to read Snellen letters because these require lines in all directions to be seen clearly simultaneously. The same thing applies to the DB1 slide. For this reason the visual efficiency test will screen out more errors of refraction than the sharpness of image test, and it appears useless therefore to add the sharpness of image tests to the series. The visual efficiency test could be carried out at the reading distance to supplant the sharpness of image test at the near point.

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HEALTH INSURANCE

For some time the subject of a National Health Program has been before the people of this country and especially before the various professional elements whose services would be used in some degree should such a program be placed in effect. These proposals have been made by various individuals and organizations and the matter was recently officially placed before the public at large by the President, who in submitting his proposal for a joint system of federal and state compulsory health insurance, asked Congress to give the program its "careful study." This is certainly putting it mildly, since the program envolves so many vital economic and professional issues that Congress cannot expect to act wisely without the most searching consideration of every phase of the plan over a period long enough to inform itself and the public thoroughly.

Health Insurance is no matter to undertake quickly or emotionally, despite the fact that there is an admitted lack of adequate medical dental and optometric care for a large portion of the population in some sections of the country. Yet up to the moment, the thinking on this subject has been handled in just that manner. The President's interdepartmental committee's report and recommendations, which he transmitted with his message, is based upon the theory that only the United States Government with the cooperation of the States, can meet those needs.

The AMERICAN JOURNAL OF OPTOMETRY believes, as the President and his committee do, that there is a serious need for an extension of health services on some basis that will enable all groups to possess them at a cost that is not too burdensome. But the final plan is one which must produce these needed services and still not interrupt the splendid advancement now being made in the professional health fields.

In his address the President informs the public and congress that the committee's recommendations are based upon reports prepared by its technical experts, and that both recommendations and reports were discussed at the National Health Conference held in Washington last June under government guidance. He said that at that conference, attended by many representatives of various professions and local health departments, there was agreement on these two fundamental points: first, "the lack of adequate medical care for many groups," and, second, "the failure to make full application of the growing powers of medical science to prevent or control disease disability." This statement is misleading since it fails to take account of the fact that the Health Conference was wholly a governmental affair, its program having been prepared long before the conference was held. His statement also makes no mention of the fact that the medical profession, after agreeing to the two fundamental points, disagreed wholly with the major proposal, which was to set up a system of federal and state health insurance.

This disagreement on the part of the Medical profession was based on the belief that such a system would mean the complete socialization of medicine, controlled and directed by the government with the obvious losses in the lowering of medical standards and the evils that flow from political control. If our information is correct, that is still The American Medical Association's position, just as it is the position of not a small part of the nation's population including the writer.

The President announces that no major extension of the federal government's health service is planned. The program is to be administered by the various states, with the aid of federal money (presumably, 50 per cent of the funds). Such a program has obvious advantages, but it also has so many disadvantages, and presents so many evils that these are quite likely to destroy the advantages.

In considering the matter, let us assume that the administration of this program is to be decentralized on state lines. Does that eliminate the danger of politics or governmental control? Not at all, for each state must appropriate its share of the funds, and that means both political and social consideration of the problem each and every year. It means a state department, which must and will perpetuate itself in office by a steady flow of the state and federal funds, and that always means political maneuvering. If any one doubt this, let him consider the persistency and thoroughness with which county agricultural agents in many of the states play politics today, not only to keep in office, but to make sure that the government's system of crop control paid for by cash benefits is continued, and also

naturally, it means a considerable measure of control from Washington. It means a new federal bureaucracy; in time, no doubt, a new department of the government and thus a political instrument of the administration in power.

Then too, let us consider the cost. The President's plan, in time, will mean an expenditure by the government and the states of $850,000,000 every year. This is an additional burden on the taxpayers, no matter how the money is raised. If it is a pay roll tax, about which there seems to be some doubt, it means that the wage earners' purchasing power is to be correspondingly lowered, not only because a portion of his wages is withheld every week but because the employer also must contribute, and that means an increase in cost of production and the final cost of the goods produced. Such a tax certainly would make the proposed Health scheme compulsory, and that would constitute compulsory health insurance at its worst. Despite any protestations to the contrary, and these will be many, it would mean the loss of freedom of selection in the matter of medical, dental and optometric care.

Under this type of plan the state administration ultimately would be forced to engage various doctors for the work, and only the poorer and illy equipped type would be available. That has been the history of compulsory health insurance in nearly every country which has tried it.

There are many considerations to the issue which the President has raised. They should be studied thoroughly and at length lest Congress adopt a program so impractical, so unwise, so political as to destroy much of the great progress which science has made in the healing arts in this country. Extension of medical, dental and optometric service to low income group is one thing. Government domination of those in professional practice is quite another. By all means, as reasoning optometrists, let us all think carefully before we commit ourselves to any plan of this sort.

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